A-2
39

M. Fr Helger

facts you should know about Acoustics

THE INSULITE COMPANY
1527 ARCADE BUILDING
CEntral 7620
ST. LOUIS, - MISSOURI

Digitized by:

INTERNATIONAL

ASSOCIATION
FOR
PRESERVATION
TECHNOLOGY,
INTERNATIONAL
www.apti.org

**BUILDING
TECHNOLOGY
HERITAGE
LIBRARY**

https://archive.org/details/buildingtechnologyheritagelibrary

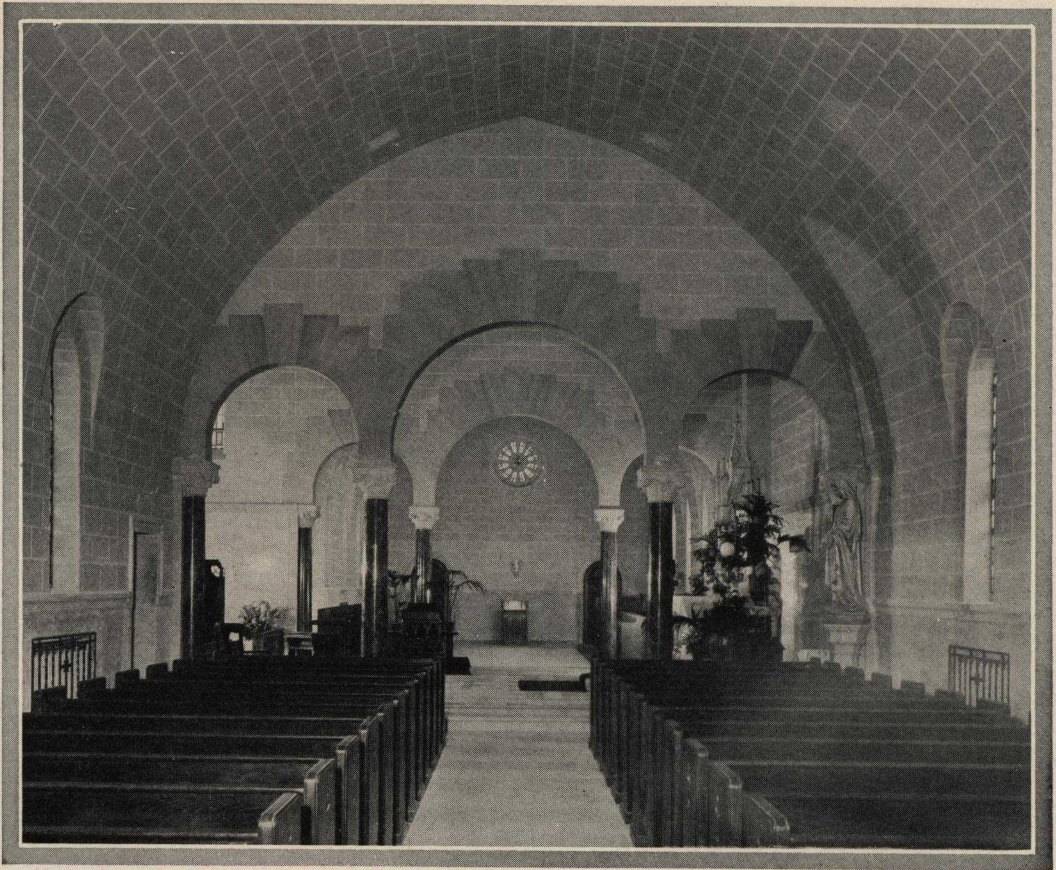
From the collection of:

**NATIONAL
BUILDING
ARTS
CENTER**

http://web.nationalbuildingarts.org

facts you should know about Acoustics

THE INSULITE COMPANY
MINNEAPOLIS, MINN.



Note how Insulite Acoustile harmonizes with the marble used in this chapel. Note, too, how the Acoustile has been beautifully fitted to the window openings.

Historical Origin

THE scientific study of architectural acoustics is a thing of comparatively recent years. In 1895 Harvard University had just completed the Fogg Art Museum, containing an auditorium which proved almost unusable. The Corporate body of the University appealed to the scientific staff of the faculty for advice and assistance in the matter, and Prof. W. C. Sabine undertook the study of the case. Two years were spent in a preliminary investigation of the questions involved, in the course of which experiments were made in a number of existing and satisfactory auditoriums. As a result, certain fundamental but previously unrecognized principles became clear, which later enabled Professor Sabine to predetermine the acoustic design of the new Boston Symphony Hall.

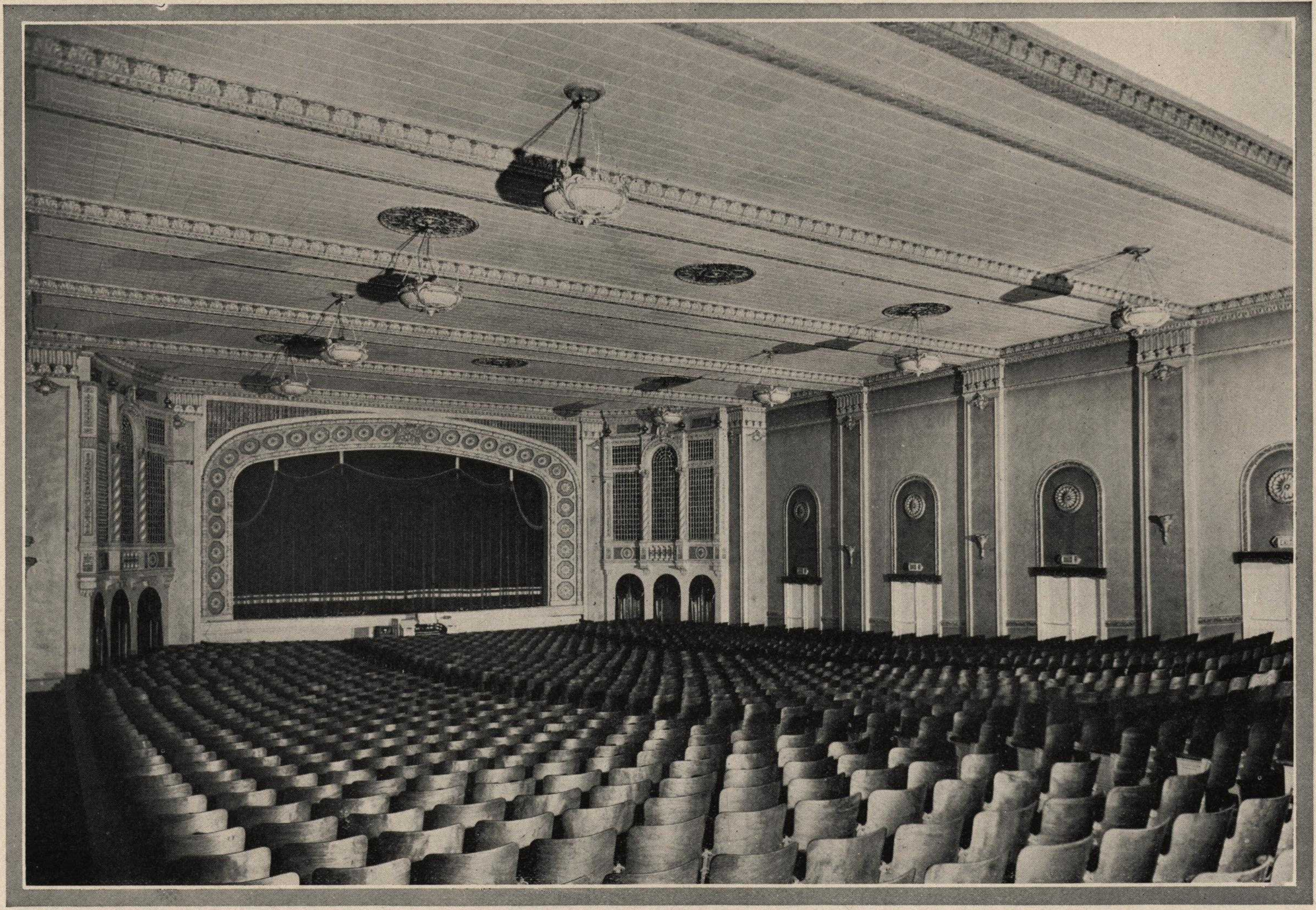
These investigations by Sabine were the pioneer scientific work in the subject. So completely and carefully were they carried out that they formed an important basis for subsequent workers to extend the theoretical foundations of the subject.

Sound and Acoustics

In physics, acoustics is known as the Science of Sound, including the production, transmission and other properties. In Architecture, the subject of acoustics is the utilization of these principles in attaining distinct hearing in all types of rooms and auditoriums.

The sources of sound are bodies in a state of vibration. When any body is set in vibration, it produces disturbances in the air around it which are known as sound waves. These waves spread out in all directions just like water waves do when you drop a pebble into a lake. Sound waves consist of a series of condensations and rarefactions, or what might be called the high and low of the wave. These are simple laws of physics.

When sound is produced in business offices, restaurants, banks and hospitals where the boundary walls, floors and ceilings are almost perfect reflectors of sound, it is obvious that energy or vibration must go through a considerable process of multiple reflection. The sound or noise created by talking, telephone bells, typewriters, and all other mechanical devices is reflected from walls to ceiling, ceiling to floor, floor to walls and ceiling again many times before this energy or vibration has been wholly dissipated.



In practically all motion picture theatres, the introduction of sound pictures necessitates the application of acoustical correction material to eliminate acoustical defects which were not encountered with the exhibition of silent movies.

Rockhill Theatre, Kansas City, Missouri.
Smith Wood-Products, Inc.
Insulite Acoustile Contractors, North Kansas City, Missouri.

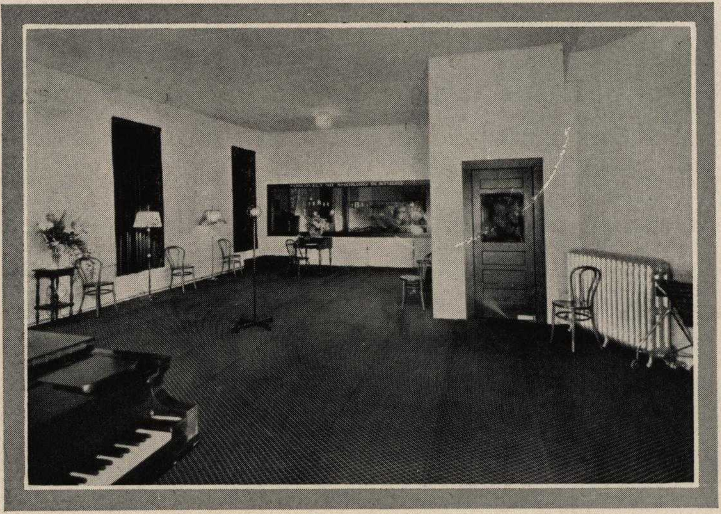
Usual Acoustical Defects

The most common acoustical defects are three—excessive reverberation, echo, and dead spots. Reverberation means a confused or inarticulate prolongation of sound owing to multiple reflections. The usual term, echo, means a definite repetition of a sound after an interval of at least a seventeenth of a second due to a single reflection. Dead spots and sound foci occur as a consequence of echo-producing conditions, and are particularly prevalent in buildings with smooth, curved surfaces.

Reverberation

Excessive reverberation is the most common acoustical defect in auditoriums. A sound produced in a room is reflected back and forth from walls, floor, and ceiling; a portion being absorbed at each reflection until its intensity is so reduced that it becomes inaudible. This prolongation of sound after it has left the source is called reverberation. It is a common experience to note that reverberation in an empty room is reduced with the introduction of furniture. In auditoriums, a certain amount of reverberation is desirable in order to increase the loudness of sound, and to satisfy an esthetic taste which psychologists have found to be present in the human mind. This esthetic aspect is particularly important in the case of music where sonority, or the blending of one tone into another to produce pleasing effects is considered. However, in speech, auditors may have difficulty in understanding a speaker if this condition prevails. The persistence of a sound will cause a blending of tones and an overlapping of syllables producing a hopeless confusion. In the correction of this defect in auditoriums, an average reverberation time which is somewhat short for music and slightly long for speech, yet quite satisfactory for both, is chosen.

It has also been found that there are other important factors to be considered which affect reverberation time, such as size of audience and the volume of the room; the best arrangement for good acoustics resulting from a compromise which satisfies average conditions.



Radio Broadcasting Station, KFH, Wichita, Kansas, where Insulite Acoustile was used for aiding the clarity of music or speech picked up by the microphone.

Smith Wood-Products, Inc.,
North Kansas City, Missouri,
Insulite Acoustile Contractors.

Echo

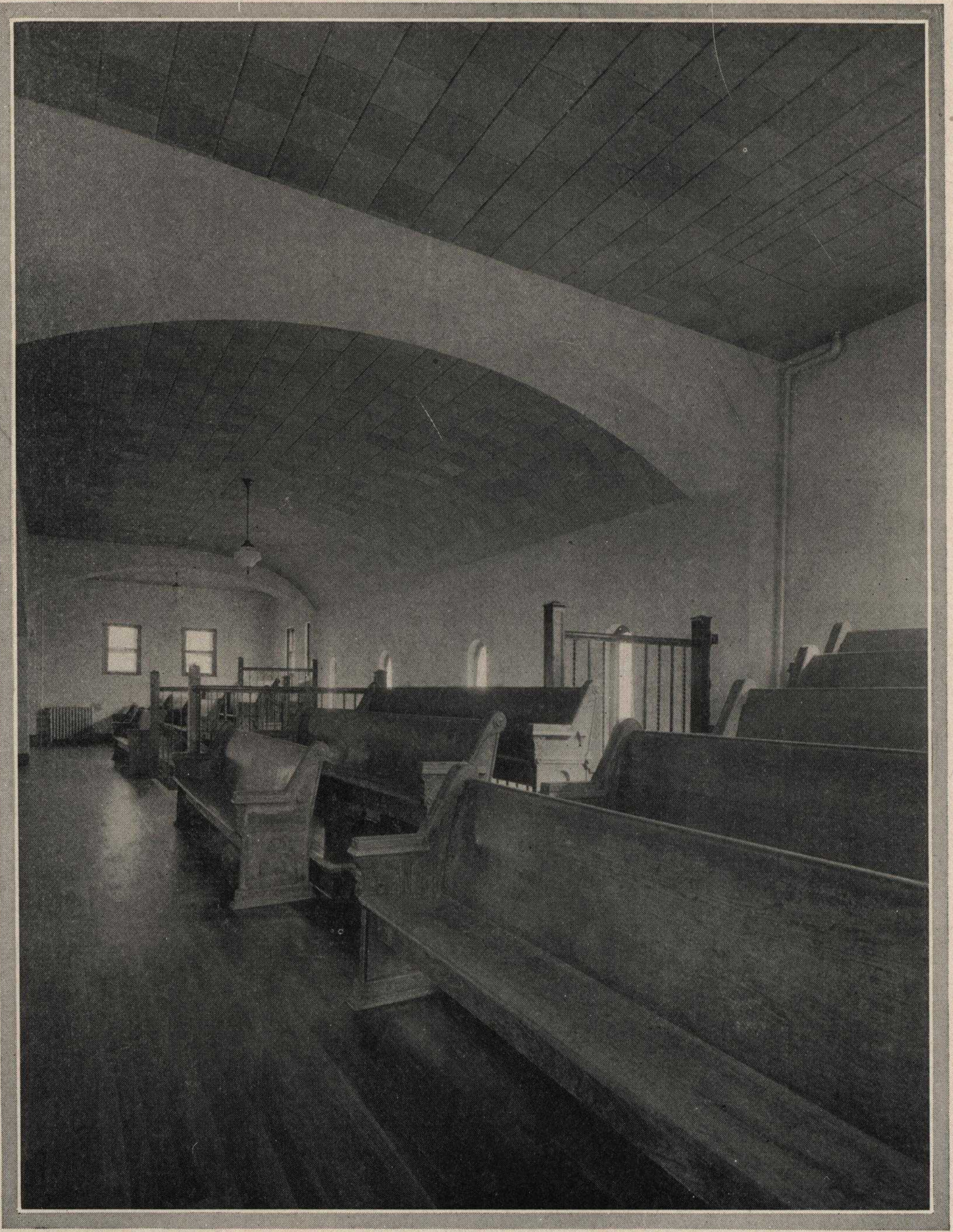
Echo arises by reflection of sound from flat, smooth walls and ceilings, just as a flat mirror may reflect a beam of light without scattering it. As an acoustical defect, echo may be considered second in importance to reverberation. There are two methods of correcting this defect, and have been designated as "surgical" and "medicinal." The first of these consists of changing the angle of the wall so as to direct the incident sound waves so that they may be absorbed. This method is usually a costly procedure and may also decrease existing architectural beauty. The second, or "medicinal" method is to apply sound absorbing material on the reflecting walls which will weaken the incident wave by absorption. This latter method is more economical and usually more effective than the "surgical" method; and, since Insulite Acoustile has proved itself so eminently successful as an absorption medium, the residual reflection component is reduced to a value so low as to destroy the formation of echoes.

The lapse of time before an echo is heard is due to the fact that the reflecting sound from the wall or ceiling has traveled a greater distance than the sound which comes directly to the ear from the source. This difference in path length may be such as to cause audition confusion. The reflected sound of a spoken syllable or of a note of music may arrive at the ear at the same time as a later generated syllable or note which has traveled by direct path, and so cause a condition of acoustic intelligibility.

Generally speaking, auditoriums are less likely to exhibit troublesome echo when their outlines are of the rectangular type with straight walls and ceiling than when curved walls or ceiling are employed.

Dead Spots and Sound Foci

Dead spots and sound foci result from echo-producing conditions, and are found particularly in rooms with smooth, curved surfaces. Sound travels through the air as a wave of alternate compression and rarefaction. If a reflected sound wave is sufficiently delayed, it may happen that the compression of the directly transmitted sound and the rarefaction of the reflected sound arrive at the ear at the same time, neutralizing each other's



Insulite Acoustile is here used beneath balcony to aid the hearing of those persons in the rear of the church.

Shorter M. E. Church,
Denver, Colorado.

effect and producing a diminution in loudness. If the reflected sound travel is increased or decreased either side of the above condition, it may happen that two compressions coincide, producing an unusually loud sound. The usual cause of such sound foci is a curved wall or ceiling which concentrates the sound to a focus.

Since dead spots and sound foci arise from the same cause as echo, their removal may be brought about by the same treatment; great care and experience being necessary in order to locate the particular portion of the room which is responsible for the production of a dead spot. The reflecting point once found must be treated in such a way as to decrease its power of regular reflection.

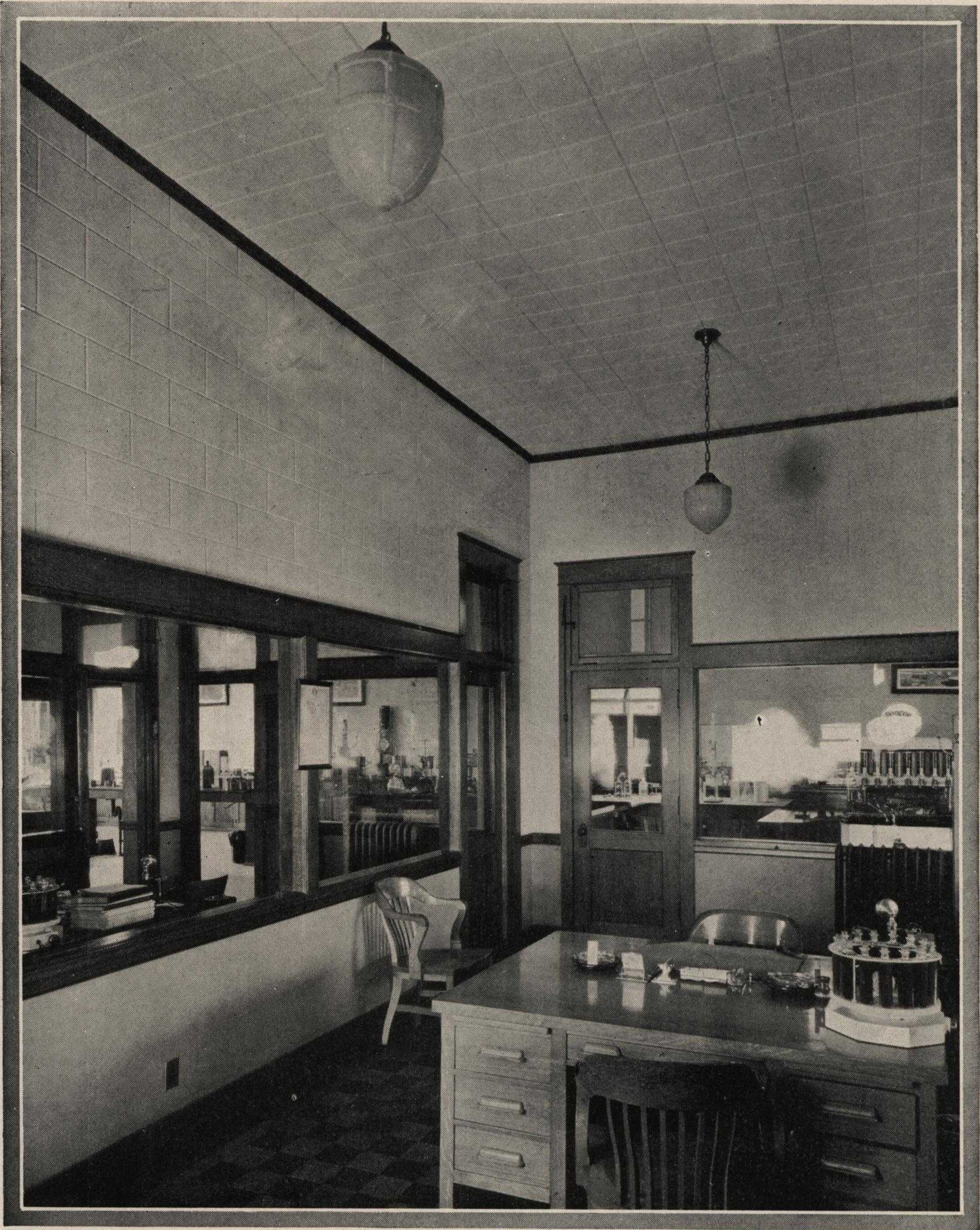
Planning for Good Acoustics

In planning for good acoustical properties in any type of room, we must consider three factors—shape, size and interior finish. Shape and size are predetermined by existing factors, but the interior finish can be selected to fit the purpose.

The Essentials of an Acoustical Material

In planning buildings with a view toward better acoustical conditions, there has been a growing tendency to use materials of a sound absorbent nature. Because of the nature of such a material it should be usable over a wider range of conditions, and, if of the right type, it can be used not alone in new buildings, but can be used in halls, or auditoriums, or rooms already built, to correct unsatisfactory acoustical conditions.

The requirements of such a material are: first, that it be of uniform sound absorption efficiency over the range of tones encountered; second, that it be of pleasing appearance in its natural form so as not to necessitate expensive decorating costs; third, that it be durable and permanent; fourth, that the cost of application and upkeep be low; fifth, that the light reflection efficiency of the material be high enough to provide satisfactory lighting conditions.



Private offices benefit as much as general offices from an application of Insulite Acoustile.

How Insulite Acoustile Fulfills Requirements

It has been pointed out above that there are a number of important essentials for any acoustical material to fulfill if it is to be efficient in the wide range of uses to which such materials may be subjected. The first essential, of course, is that the material have a uniform and satisfactory efficiency in the absorption of sound, and in this particular requirement Insulite Acoustile ranks high. Produced under the best manufacturing standards and conditions, Insulite Acoustile is made of felted wood fibers, into rigid boards or sheets, composed of countless "dead air" cells, which greatly aid in the absorption of sound. The results of scientific sound investigation on Insulite Acoustile are given on page 21.

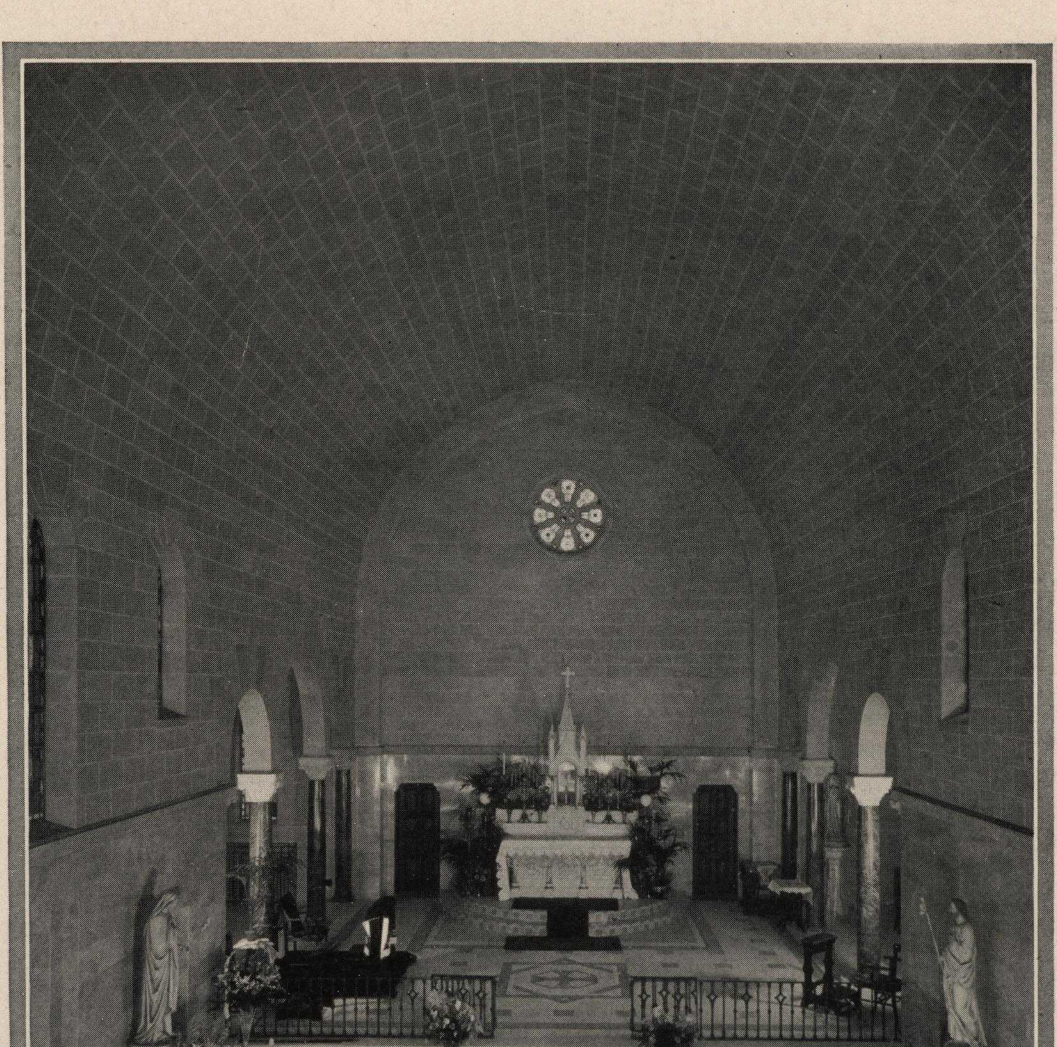
The natural color of Insulite Acoustile is a light cream or ivory shade. The various sizes and shapes of Acoustile may be arranged in an endless variety of patterns to suit individual tastes, some suggestions for these arrangements being given on pages 24-27. Naturally a wide range of other original designs may be created to suit conditions presented by various rooms. An indication of how Insulite can be worked may be seen in the illustration on page 2 where it has been cut to fit window openings and arches. The surface of Insulite is of a burlap texture, presenting a rich looking appearance when the material is in place, whether it be left in its natural state or decorated as suggested in the specifications appearing on page 27.

Because of its strength and rigidity Insulite Acoustile can be used successfully in all types of rooms, halls, auditoriums, and gymnasiums.

Owing to the fact that Insulite Acoustile is easily cleaned by means of brushing or vacuum, the cost of upkeep is particularly low, a factor of importance to building managers.

As shown on page 21 the light reflection efficiency is high and closely within the range required for best results in the satisfactory lighting of a room.

Insulite Acoustile, in addition to fulfilling efficiently the requirements of an acoustical corrective material, adds another advantage that should not be overlooked. This advantage consists of its insulating efficiency against heat and cold. Here is a material that not only solves the acoustical problem, but at the same time provides much needed insulation, making the room or building easier to heat in winter time, cooler in summer, and does away with the condensation of moisture on walls and ceilings which has been so costly in many public buildings.



In this chapel Insulite Acoustile blends harmoniously with the marble used part way up the walls.

House of the Good Shepherd,
Wauwatosa, Wisconsin.
Eschweiler & Eschweiler, Architects,
Milwaukee, Wisconsin.

Because of the fact that no two sets of conditions are similar we are setting down no definite rules here. Members of the Engineering Department of the Insulite Company, Builders Exchange, Minneapolis, Minnesota, will be glad to co-operate with architects and engineers to aid in solving acoustical problems as they come up. There is no charge for this service, and the department welcomes opportunities to co-operate with you.

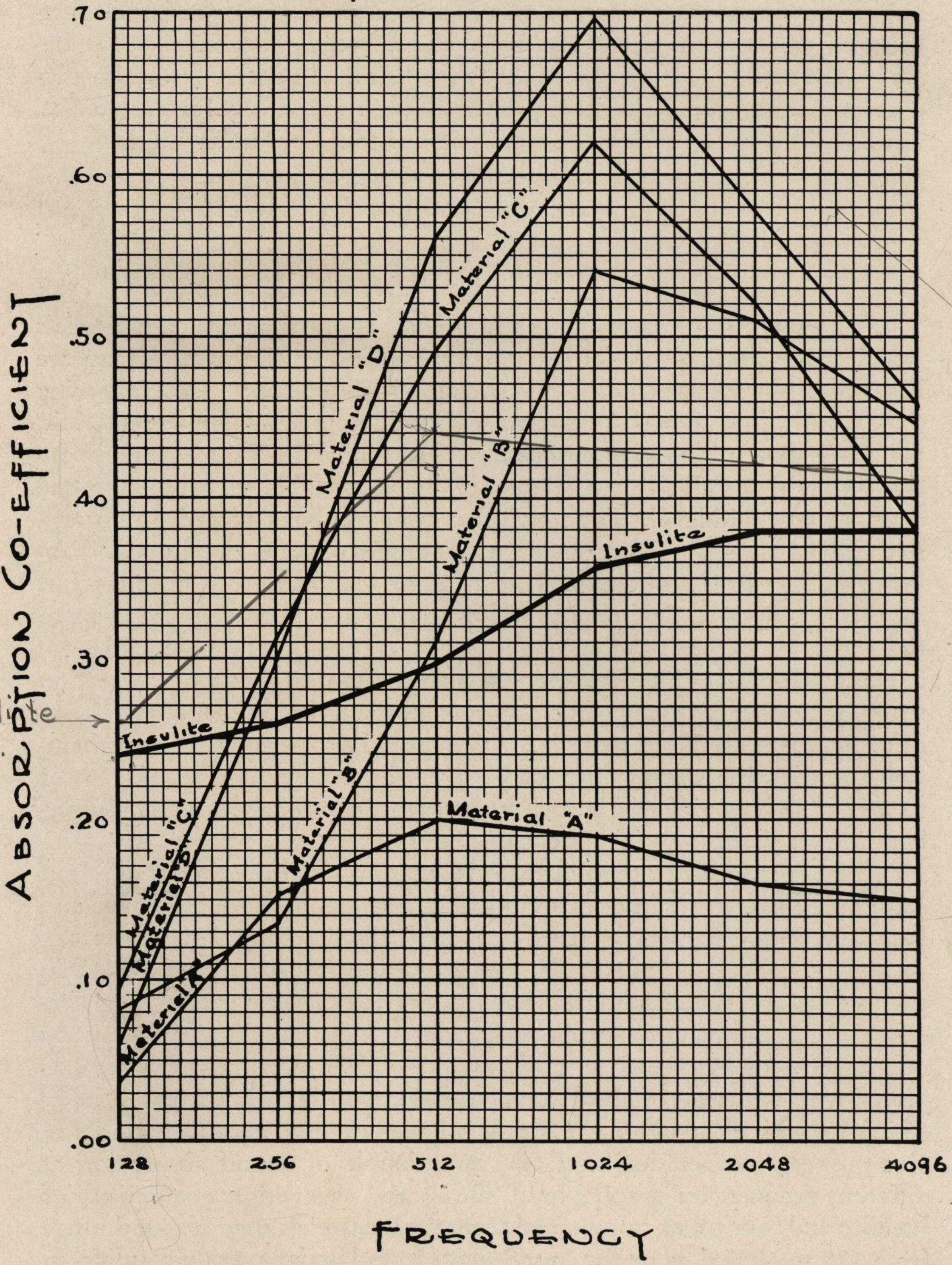
Factors Determining Selection of Sound Absorbing Materials

There are two major factors in the selection of acoustical materials which have been given too little consideration in the past. These are Resultant Correction Value and Economic Efficiency. The following graphs and tables give a comparison of these factors for different materials.

The absorptions of materials have been judged almost entirely from the values determined at a frequency of 512 double vibrations or one octave above middle C. Too much emphasis has been placed on absorption values thus obtained when calculating acoustical conditions. Professor Sabine in a work published in 1906 indicated this problem but unfortunately acoustical engineers have given too little consideration to the factors involved. Sabine showed that reverberation depends not entirely upon the size of the room and absorption value of correction material at one frequency but also depends on the pitch of sound. In other words, correction material which would provide proper reverberation for the high notes of a violin leaves the possibility that the lower tones of the bass viol will be highly accentuated due to excessive reverberation at these lower frequencies.

The necessity of taking into consideration reverberation at different sound pitches is brought out forcibly by the examples of auditoriums and halls now in use supposedly fully corrected which do not give satisfactory results for some types of sound. This condition has been accentuated in the past by the use of materials having high absorption factors at a frequency of 512 d. v. and extremely low absorption factors at a frequency of 128 d. v. or even 256 d. v. There are auditoriums, now in use, corrected with materials of absorption coefficients as high as 65 and 70% at 512 d. v., which for sounds at 256 d. v. have only half enough material to give proper reverberation time. As an example of sound absorption at different frequencies graph No. 1 shows the absorption coefficients of Insulite and four other commercial acoustical materials over a sound range from 128 to 4096 d. v. or the sound range found under average conditions.

GRAPH 1



1 1/2" Insulite Acoustile.

COMPARATIVE ABSORPTION VALUES

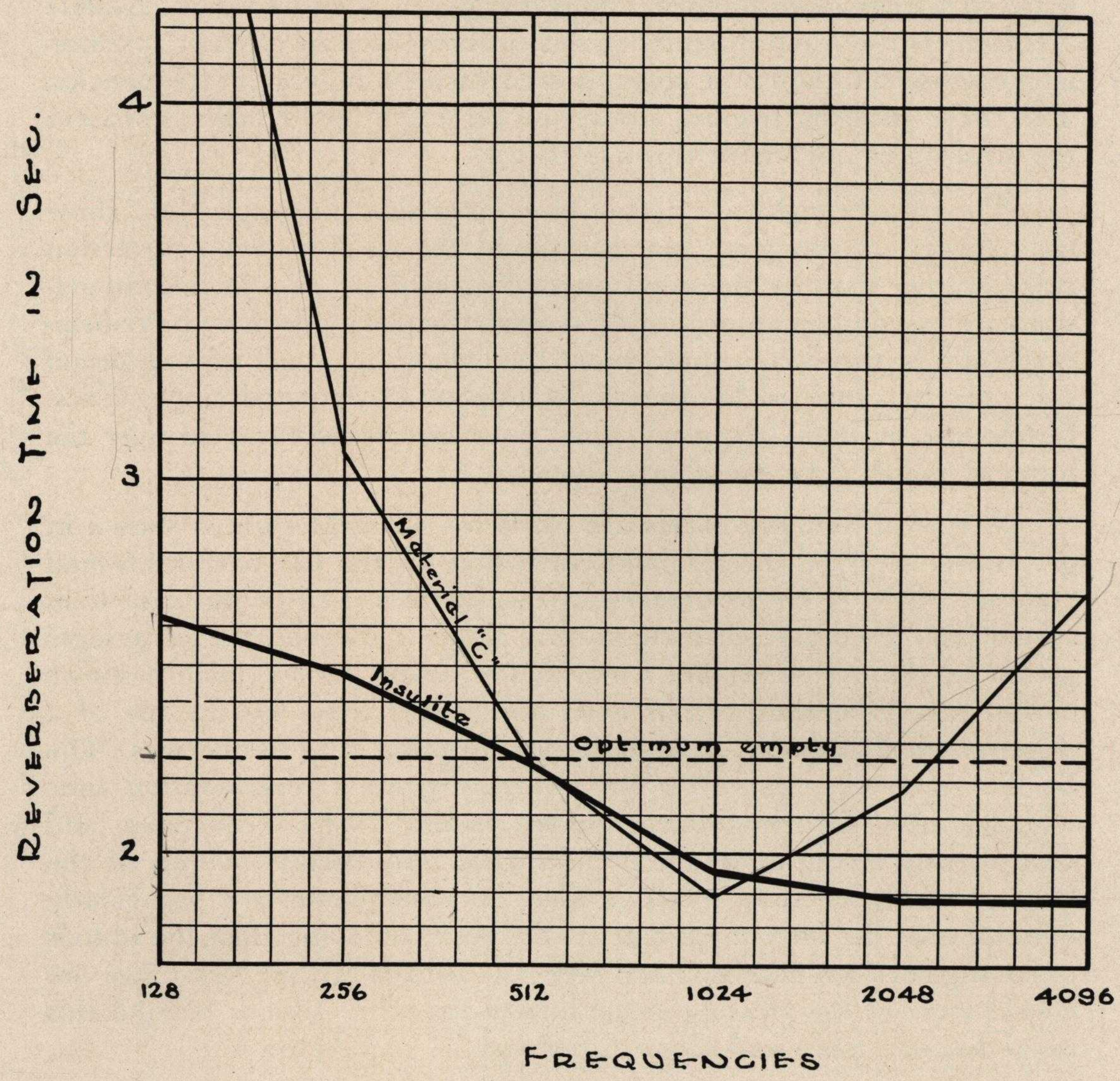
It is obvious by brief study of graph No. 1 that an auditorium properly corrected at 512 d. v. with material "D" would have but 50% of the requirements at a frequency of 256 d. v. Variation of the amounts of material is, of course, impractical and the only possible methods of providing correct acoustics over the entire sound range are either by the use of two materials with reverse characteristics over the sound range, or a material with a more uniform absorption over the entire range. Insulite Acoustile is the result of study of this problem and an attempt to eliminate excessive variation of absorption coefficients at different frequencies. The curve showing Insulite absorption on graph No. 1 makes apparent the advantages obtainable through its use.

The facts brought out in the above discussion and graph No. 1 show the necessity of designing for acoustics by the use of resultant correction curves rather than by the point method of analysis, in which computations are based upon absorptions at a single frequency. It must be remembered also in this design that proper tone effects in a hall or auditorium can only be obtained by the elimination of accentuated single tones. Either low or high frequency tones must not be accentuated over the tones at middle C or one octave above.

A typical resultant correction curve for an auditorium is shown in graph No. 2 giving the resultant correction by the use of Insulite and material "C." A larger amount of Insulite was used in this case than would have been used of material "C" alone. However, the advantages gained by the use of Insulite are evident. Graph No. 2 plainly shows excessive reverberation of the lower and higher tones by the use of a material which does not have uniform absorption at all frequencies. The Insulite correction curve on the contrary gives a reverberation time which is only slightly above optimum at the lowest frequencies, and very slightly below optimum at the higher frequencies. Sounds of the lower and higher frequencies it must be remembered are particularly noticeable to the human ear and are far more annoying than the sounds occurring between middle C and high C. Sounds within this range are always more or less pleasing to the human ear while sounds beyond this range become more and more disturbing.

In summing up the conclusions arrived at by the foregoing discussion, particular emphasis is placed on the necessity of uniform absorption and absorption of tones of excessively high or low pitch. In order to obtain the advantages accruable by the use of uniform absorption material it is, of course, necessary to use larger amounts of such a material.

GRAPH 2



RESULTANT CORRECTION CURVES

Instead of being a disadvantage, this is in most cases a valuable characteristic. There are extremely few cases where enough material of an average coefficient cannot be placed in a hall or auditorium. In fact, the use of small amounts of absorption material often leaves large reflective areas which establish sound foci otherwise known as echoes. The use of larger amounts of material which enable complete elimination of reflective surfaces is not only an advantage but in a great many cases an absolute necessity. The design of an auditorium to eliminate such reflective surfaces has been stressed repeatedly by most of the eminent acoustical research engineers. The practical application of such recommendations is, however, oftentimes entirely neglected because of the desire in the past to use small amounts of highly absorptive materials efficient only over a very small sound range. It is obvious that provided cost is within comparison, uniform absorption material is highly preferable.

Economic Efficiencies

Economic design depends not only upon absorption coefficients per square foot but also upon cost per square foot applied. The combination of these two factors will plainly show the comparative economic efficiency of different absorption materials. The following table shows these comparative economies based on the cost of Insulite which is shown as unity. Comparative costs are shown only in their relation to Insulite and are at the best approximate as these costs will vary. However, the method shown of establishing a table of comparative economic efficiencies can be used in establishing a similar table of materials at any given cost.

Material	Absorption Units Per Sq. Ft. 512 d. v.	Sq. Ft. Required Per Unit Absorption	Approx. Comparative Cost per Absorption Unit	Comparative Economic Efficiency
Insulite	.30	3.33	1.00	100%
Material				
A	.20	5.00	4.00	25%
B	.31	3.25	3.78	26.5%
C	.49	2.04	2.44	41.0%
D	.56	1.78	2.06	48.6%

This table is fairly comprehensive in the materials it covers, that is, most of the widely used absorption materials are represented or are on a par with one of the materials listed. Insulite Acoustile permits high economical efficiency because of the inherent simplicity of the units themselves and the economical methods of application in the finished structure.

Insulite Acoustile is especially adapted to the treatment of music practice studios.

The above analysis of the factors governing the selection of absorption materials is typical, and, while conditions will vary with every new building or auditorium, the same general law will hold true. It is recommended that acoustical design take into consideration the points embodied in this analysis.

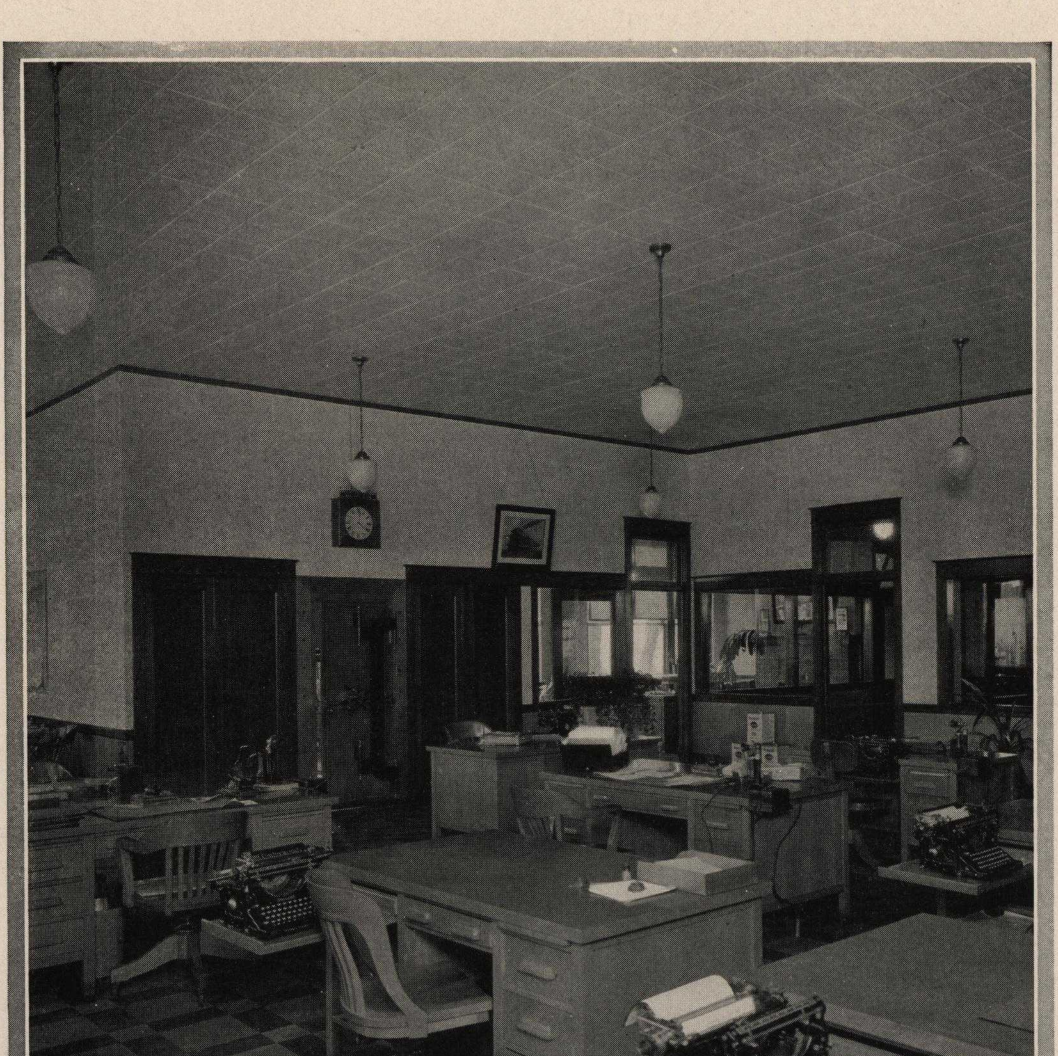
Acoustical Correction of Offices

The correction of modern business offices presents a somewhat different problem than the design of halls and auditoriums where large bodies of people are present and musical effects are desired. Noises occurring in business offices such as typewriters, moving of the chairs, rattling of papers and incidental noises caused by hard objects are practically all of an extremely high sound frequency. The correction of conditions within an office for this reason should be concerned with absorption efficiencies above the ordinary speaking range. Insulite Acoustile provides highly satisfactory absorption at these frequencies as can be seen by study of chart No. 1 or referring to test reports found on page 21. The purchase of acoustical materials for such correction should also be governed by the two major factors previously discussed; namely, that of the efficiency obtainable at the sound frequencies encountered, and the comparative economic efficiency of the various materials. Such a comparison indicates plainly the high value of Insulite for this type of work.

Result of Sound Absorptive Tests of Insulite Acoustile

The authority for the values given on the following page is Vern O. Knudsen, Ph.D., of Los Angeles, California. The figures shown indicate the portion of the sound energy absorbed at each impact of a sound wave.

The method of conducting the tests was essentially the reverberation method as described by Dr. Knudsen in the Journal of the Optical Society and Review of Scientific Instruments for November, 1926. Forty separate measurements of the time of reverberation were taken for each condition tested. The coefficient at each frequency is based upon the average of these forty measurements.



In offices, Insulite Acoustile adds to business efficiency by its ability to absorb sound and decrease distracting noises.

Pennsylvania Petroleum Co., Offices,
North Kansas City, Missouri,
Smith Wood-Products, Inc.
Insulite Acoustile Contractors.

The test area for the single layer of Acoustile was 64 square feet. The test area for the double layer was 48 square feet. In the case of the double layer test, two layers of Insulite were separated by a 3/4-inch air space using wood strips 3/4-inch by 1 3/4-inch spaced 24 inches on centers. The coefficients of sound absorption obtained in the two different tests are given in the following table:

	Coefficients of Sound Absorption At Different Frequencies				
Sound Frequencies	128	256	512	1024	2048
Single layer	.24	.26	.30	.36	.38
Double layer	.30	.31	.34	.37	.40

Results of Light Reflection Tests

A wall or ceiling surface should have a coefficient of from .55 to .70 in order to provide satisfactory lighting conditions within a room. The factor of .55 to .70 is the amount of light striking a surface which is reflected back into the room, the balance of light being absorbed.

The following light test was made by the Electrical Testing Laboratories of New York City.

Material	Sample Color	Sheet Size	Reflection Factor
Insulite	Cream	11″x8½″	.64
Material #2	Brown	12″x12″	.14
Material #3	Sand	11″x8½″	.40

Test

Measurements were made of reflection factor by using diffused light of equal intensity from all directions at a color temperature of approximately 2,100° K. The samples were viewed at an angle of 12° to the normal.

As shown by the tests, Insulite comes directly within the desired reflection coefficient range; consequently it has a great advantage from the standpoint of lighting effect when left in its natural state for acoustical purposes on the walls and ceiling of a room.

Insulite Acoustile was used, not only on the flat wall here, but in the curved wall space of the sanctuary, where a herringbone pattern was followed.

Suggestions for Application

Cementing and Nailing to Plaster

Insulite Acoustile, ½″ in thickness, is light in weight, should be cemented with a standard brand of Linoleum cement and each tile should be nailed with 1″ brads set into tile, a nail to be placed in each corner and one in center of each tile. The plaster of the ceiling or wall must be hard and firm. On new work the putty coat may be omitted, providing the brown coat is finished under a float to an even surface.

Nailing to Wood Strips

Insulite Acoustile may be applied on wood nailing strips spaced 12″ on centers, or in accordance with the requirements of the design, nailed as specified for plaster. Nailing strips to be applied on 2″ square sleepers anchored to concrete or other masonry construction. In concrete or brick work, plugs are satisfactory or, on new work, clips or grounds can be placed during construction.

Application to Wood Surfaces

In the case of a church, auditorium, or room that has a wood ceiling, Insulite Acoustile may be applied as specified for plaster.

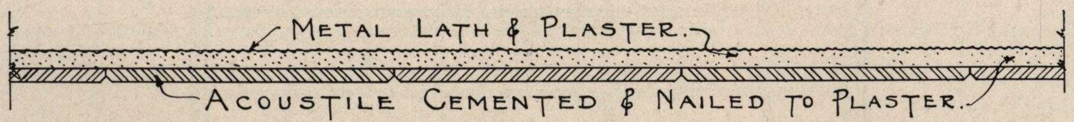
Wall and Ceiling Correction Panels

In many cases the area of correction with Insulite Acoustile required is less than the total area of ceiling or wall. The contractor is to furnish and install 3/4"x1 3/4" grounds at the panel edges to which the finish moulding will be nailed after the Insulite Acoustile has been applied. (See detail.) For moulding suggestions, architects may design mouldings in keeping with interior finish. These mouldings should be furnished and put in place by the Acoustical contractors.

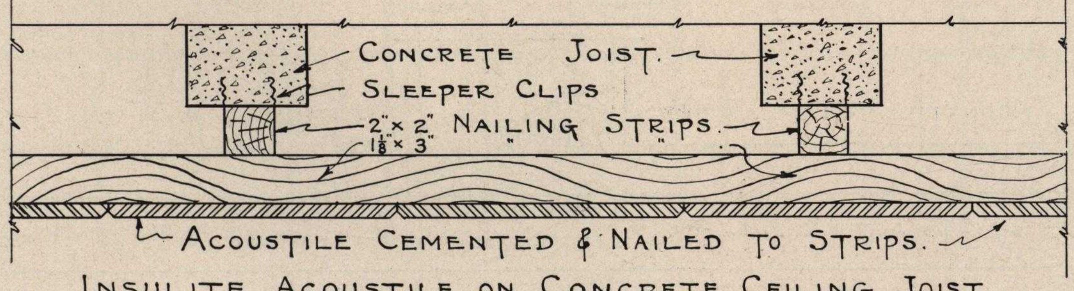
Decorating

Insulite Acoustile may be decorated by an endless variety of color effects, by using either water or alcohol stains, which may be applied in stencil designs. Suggested designs of this type are shown on page 27. It is very important to remember that paint containing lead, oil and other heavy pigments if applied to Acoustile will reduce the sound absorption value, while the stain will not.

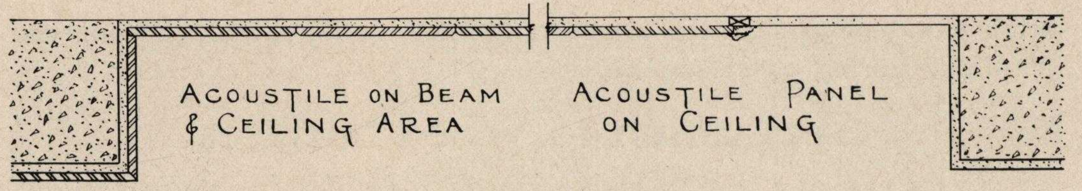
APPLICATION OF INSULITE ACOUSTILE ON CEILINGS.

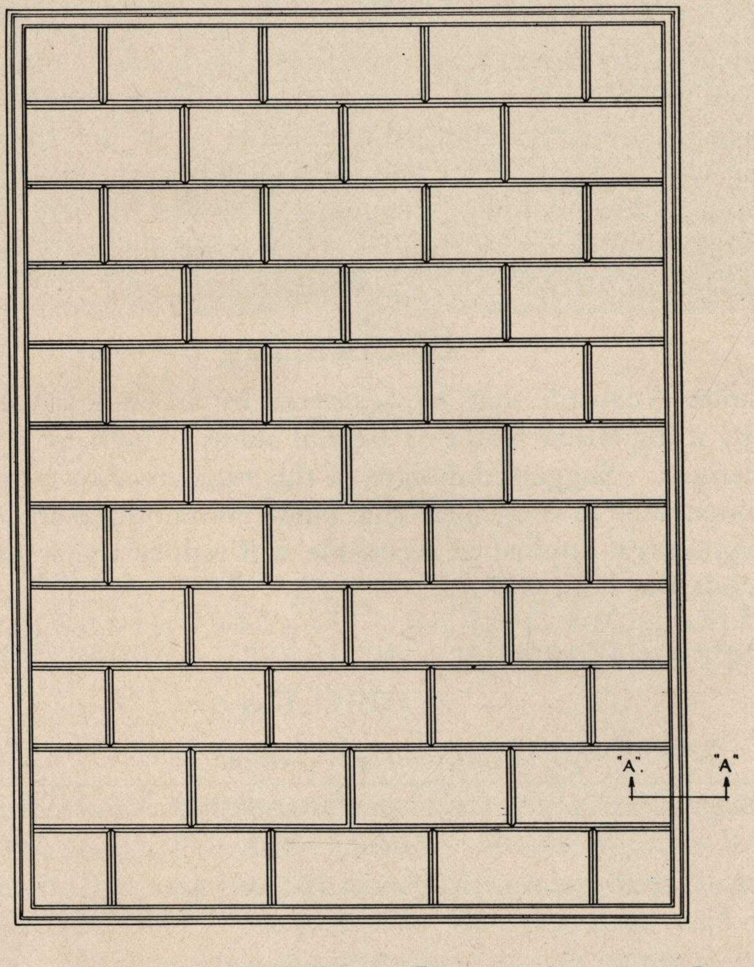


INSULITE ACOUSTILE ON PLASTERED CEILING.

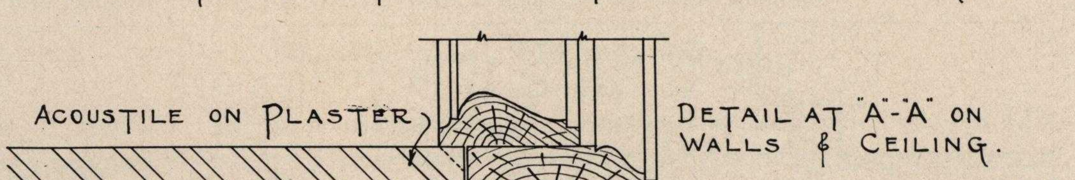


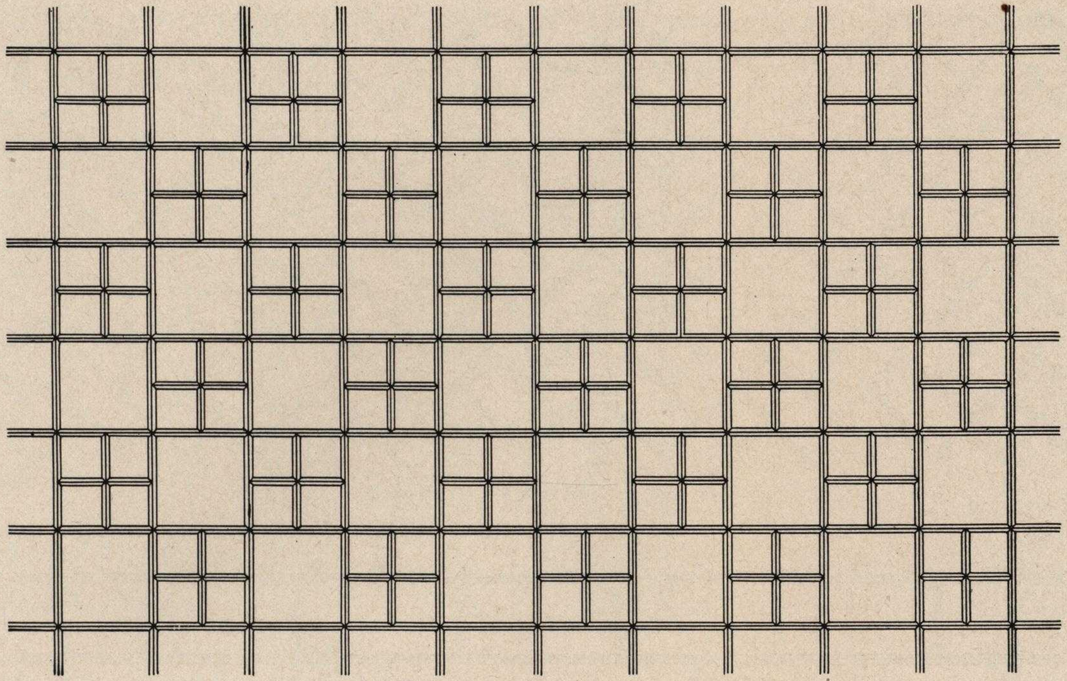
INSULITE ACOUSTILE ON CONCRETE CEILING JOIST.





Insulite Acoustile Wall Panel Ashlar Design.

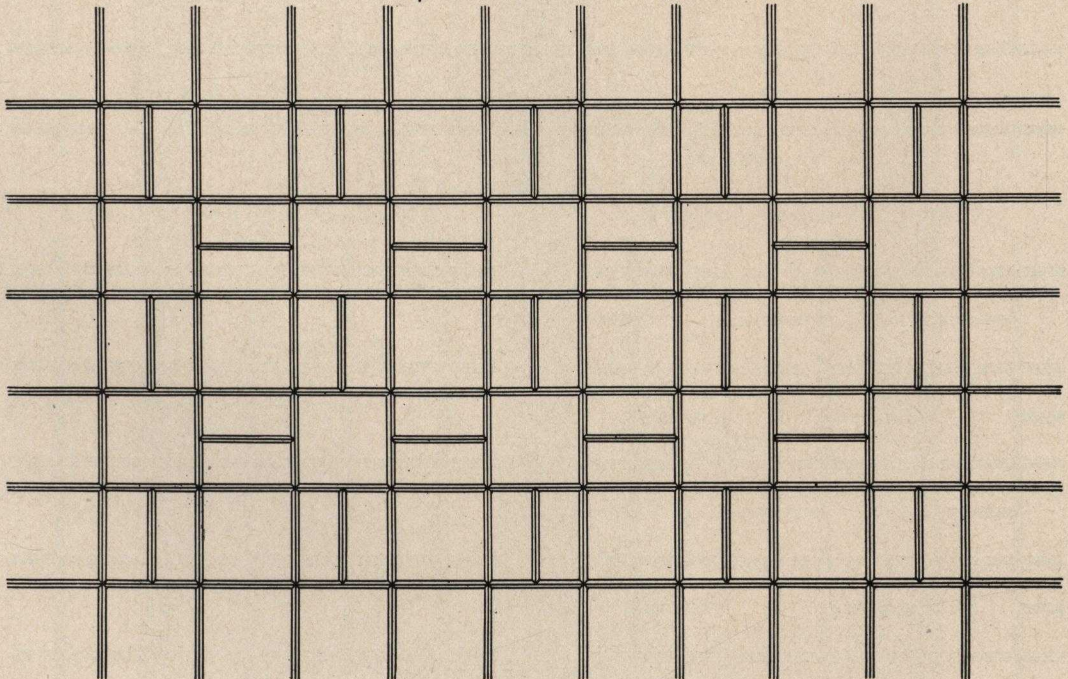


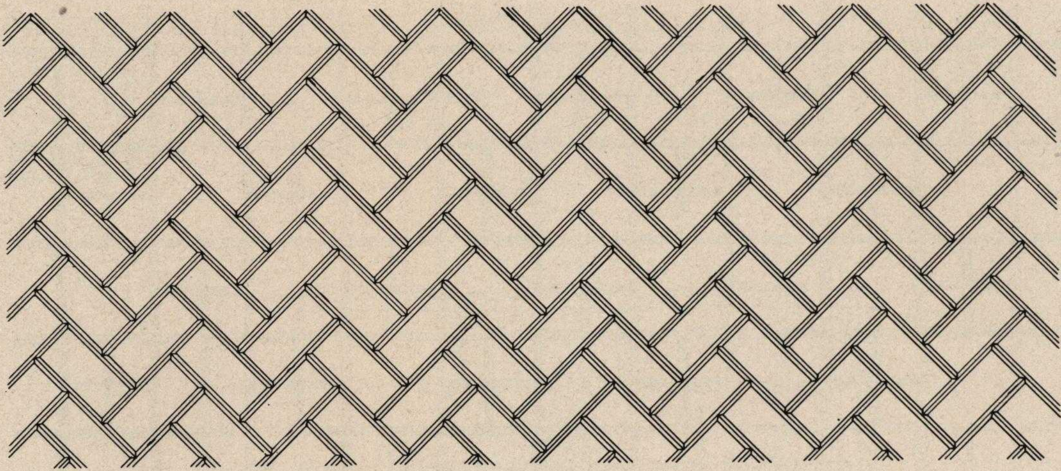


6"x 6", & 12"x 12" ACOUSTILE.

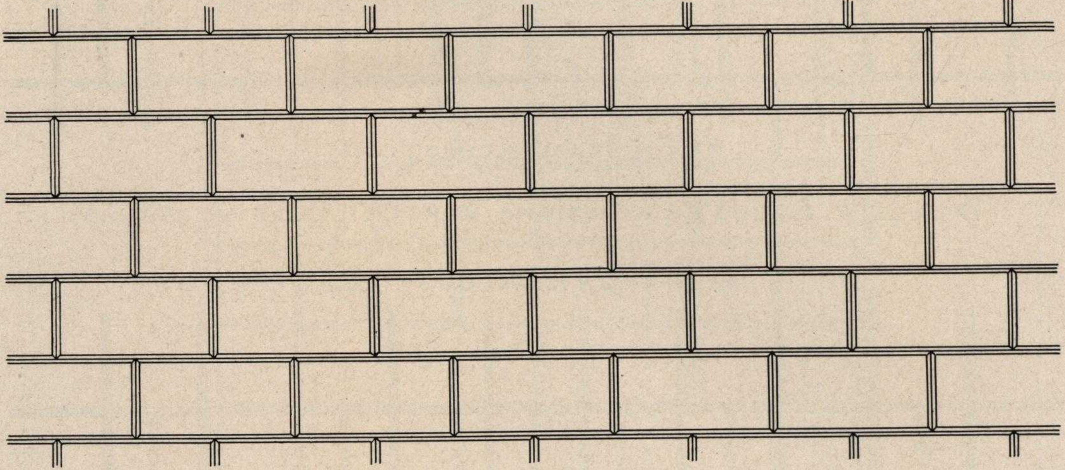
INSULITE ACOUSTILE DESIGNS FOR CEILINGS OR WALLS.

6"x 12" & 12"x 12" ACOUSTILE.



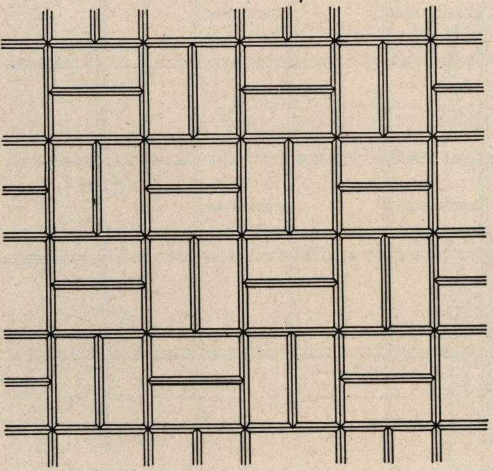


6" x 12" HERRINGBONE.

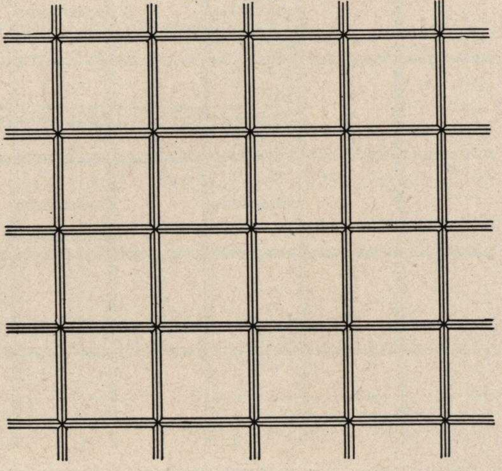


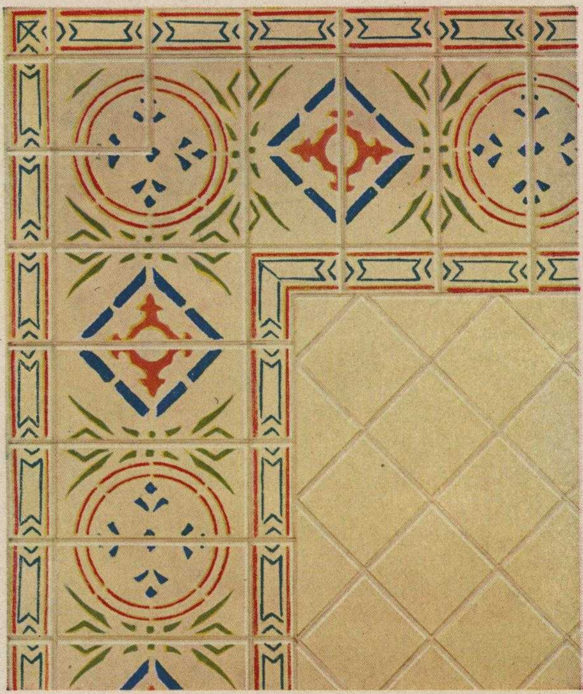
10" x 20" ASHLAR.

6" x 12" BASKET WEAVE.

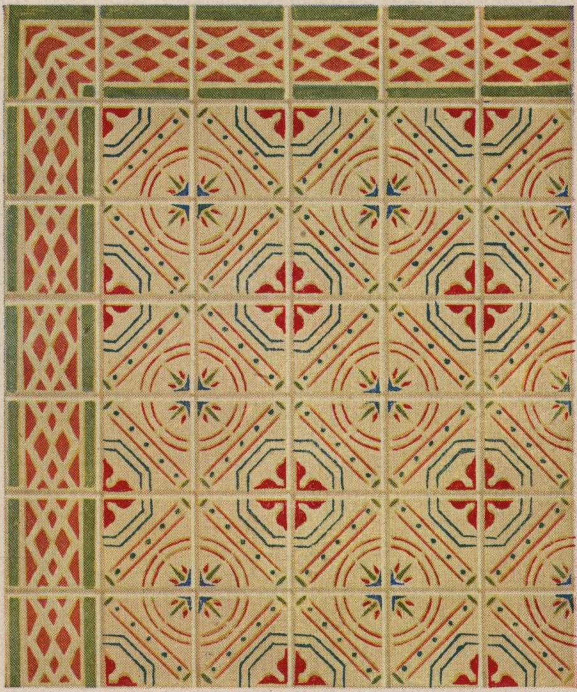


12" x 12" STRAIGHT LINES.

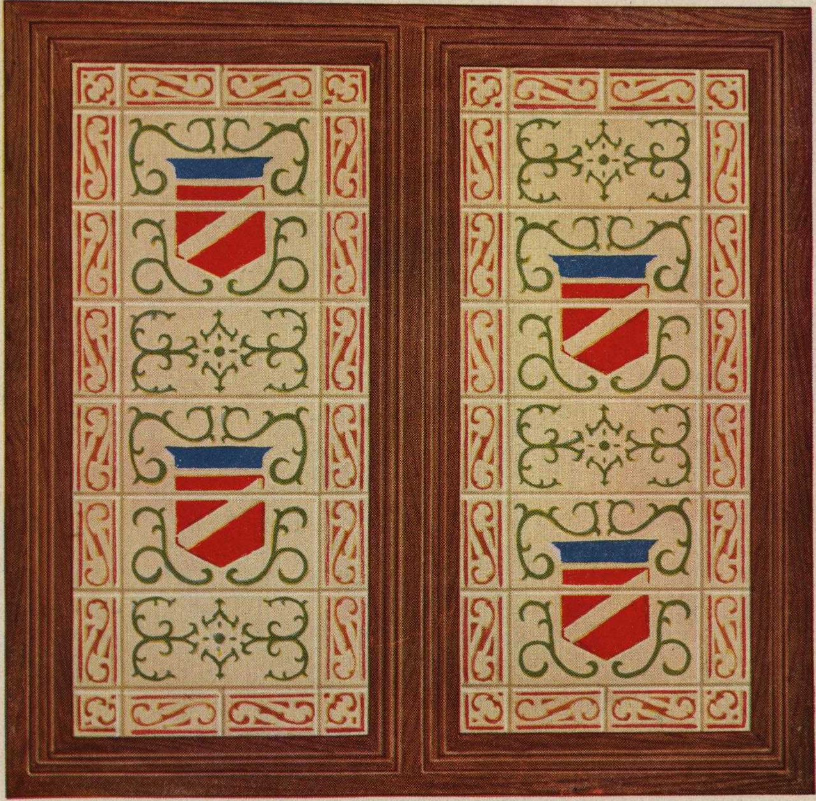




A Border Design
Using 6″x12″, 12″x12″ and 12″x24″ Acoustile



Overall Tile Design
Using 12″x12″ Acoustile



Panel Design
Using 6″x12″ and 12″x24″ Acoustile

SUGGESTED STENCIL DECORATIONS FOR INSULITE ACOUSTILE

Practically all Insulite Acoustile is applied in some one of the tile patterns as shown by details or of special design. Starting out the job properly and maintaining true lines during application are essential for the appearance of the finished installation. Members of the Service and Engineering Departments of The Insulite Company, Minneapolis, Minnesota, will be glad to co-operate with any one in working out acoustical problems.

INSULITE
the Wood-Fiber Insulating Board

NO. 26
PRINTED IN U. S. OF A.
PRINTING INC.

A. I. A. File No. 37A1

Conductivities
of
Insulating and Building Materials

THE INSULITE COMPANY
1527 ARCADE BUILDING
CEntral 7620
ST. LOUIS, - MISSOURI

INSULITE
the Wood-Fiber Insulating Board

10.60

30
30
900

The Conductivities of Insulating and Building Materials

IN considering the results of tests made to determine the conductivity values for any insulating or building material, there are two factors of vital importance. These factors are first, the density of the material tested; second, the temperatures at which the tests were made. Unless these two factors are given for a material, the test results as listed have no value.

In some cases it has been impossible for us to get the test temperatures for some of the materials listed on the following two pages, the data not having been complete in literature we have been able to obtain concerning these individual materials.

As an indication of the importance of showing test temperatures and density, so as to give a true picture of the insulating efficiency of a material, let us consider an actual case. Insulite, the wood-fibre insulating board, of 16 pound density and tested at 80 degrees mean temperature shows a conductivity value of .302. If this same material had been tested at a mean temperature of 70 degrees the resulting value would be considerably less and would appear to make Insulite more efficient than some other material which might have been tested at a higher temperature.

In the charts on the following pages wehave listed results of tests on Insulite for 12 pound, 16 pound and 18 pound density material. This refers to the weight per cubic foot of the material. For general practice we use the conductivity factor given for 16 pound density Insulite since this is equivalent to the stock we are furnishing the building field. The factor for Insulite of this density is .302 and is the factor that should be used for accurate determination of heat transmission.

Through the use of these charts it is a simple matter to figure the heat transmission of any wall. For example, let us assume that we want to find the value of a wall constructed as follows: wood siding, building paper, wood sheathing, Insulite plaster base on the inside of the studding, and plaster.

To find the overall value of any construction, it is only necessary to add the total resistance factors of each of the materials used in such construction. After this is done, the insulating value of the wall itself will be obtained by finding the reciprocal of the total sum of resistance factors, or in formula form. $\frac{1}{\text{total resistance}}$

Referring to the wall given in our example above, we find the resistance of

Outside surface resistance of lap siding	.222
Lap siding	.394
Building paper	.09
Wood sheathing	.855
Inside surface resistance of wood sheathing	.667
Surface resistance of Insulite plaster base	.667
Insulite plaster base (½″ thick)	1.65
Plaster (⅜″ thick)	.161
Inside surface resistance of plaster	.571
Total resistance	5.277

Overall conductivity factor $= \frac{1}{5.277} =$ - - - - - - .189

For the assistance of architects, engineers, and builders, The Insulite Company maintains a Service Department composed of experienced technical men with the latest insulation data at their finger tips. They will gladly work with you on any problem pertaining to the use of insulation, answer any questions that may come to your mind, and render any service within their power. There is no obligation whatsoever—the opportunity of being of service will be welcomed.

THE INSULITE CO.
General Offices:
MINNEAPOLIS, MINN.

Material.	Density in pounds per cu.ft.	Mean test temp- °F.	C.= B.T.U. loss per sq.ft. per in. thick per hour per °F. diff.	Authority	t = Commercial thickness.	Resistence $= \frac{t}{C}$	S' Inside Surface factor	$\frac{1}{S'}$	S" Outside Surface factor	$\frac{1}{S''}$	Remarks.
Insulite.	12.#	86.°	.296	Bur. Standards	$\frac{1}{2}$" = .50	1.69	1.50	.667	4.50	.222	
"	12.#	86.°	.296	"	1" = 1.0	3.38	"	"	"	"	
"	16.#	80.°	.302	Rowley.	$\frac{1}{2}$" = .50	1.65	"	"	"	"	
"	16.#	80.°	.302	"	1" = 1.0	3.31	"	"	"	"	
"	18.0#	82.5°	.311	"	$\frac{1}{2}$" = .50	1.61	"	"	"	"	
"	18.9#	82.5°	.314	"	$\frac{1}{2}$" = .50	1.59	"	"	"	"	
Celotex.	12.5#	97.°	.338	Bur. Stand.	$\frac{7}{16}$" = .437	1.29	1.50	.667	4.50	.222	
"	13.5#	70.°	.330	Gebhardt.	$\frac{7}{16}$" = .437	1.32	"	"	"	"	
"	15.#	86.°	.375	Bur. Standards	$\frac{7}{16}$" = .437	1.17	"	"	"	"	
"	15.#	86.°	.375	"	$\frac{7}{8}$" = .875	2.33	"	"	"	"	
Flax-li-num	11.2#	86.°	.328	Bur. Standards	$\frac{1}{2}$" = .50	1.52	1.25	.80	3.75	.267	
"	11.2#	86.°	.328	"	1" = 1.0	3.04	"	"	"	"	
Balsam-Wool.	3.8#	70.°	.249	Burgess	$\frac{1}{2}$" = .50	2.01	2.0	.50			
"	3.62#	72.°	.229	Gebhardt	$\frac{1}{2}$" = .50	2.18	"	"			
Corkboard	6.9#	86°	.269	Bur. Standards	1" = 1.0	3.72	1.50	.667			
"	9.98#	86.°	.302	"	"	3.31	"	"			
"	11.24#	86.°	.308	"	"	3.24	"	"			
"	14.#	86.°	.335	"	"	2.98	"	"			
"	15.6#	86.°	.351	"	"	2.85	"	"			bituminous binder
Maftex	16.1#		.337	Gebhardt.	$\frac{7}{16}$" = .437	1.30	1.50	.667	4.50	.222	test temp. not given
Masonite	19.8#		.328	"	$\frac{7}{16}$" = .437	1.33	1.75	.571	5.25	.291	" " " "
"	17.9#	72.°	.32	Rowley.	$\frac{7}{16}$" = .437	1.36	"	"	"	"	
Cabot's Quilt.	5.76#	86.°	.334	A.S.R.E.	$\frac{1}{2}$" = .50	1.50	2.0	.50			Density calculated from oprox. values
Lith board	12.5#	86.°	.380	Bur. Standards.	1" = 1.0	2.63	1.25	.80			
Fibro-felt.	11.24#	86.°	.328	"	1" = 1.0	3.05	"	"			
Lino-felt.	11.24#	86°	.299	"	$\frac{1}{2}$" = .50	1.67	1.75	.571			
Hair-felt.	18.72#	86.°	.270	"	1" = 1.0	3.70	1.25	.80			"Keystone"
Hair-Insul.	9.6#		.280		$\frac{1}{2}$" = .50	1.79	"	"			
Insulex.	12.#	75°	.40	Gebhardt.	1" = 1.0	2.50	1.25	.80			
"	18.1#	86°	564	Bur. Standards	"	1.77	"	"			
" or Pyrocell	24.#	75°	.737	Gebhardt.	"	1.35	"	"			
" "	29.4#	86°	.900	Bur. Standard	"	1.11	"	"			

SERVICE DEPT.
The Insulite Co.
Minneapolis - Minn.

STANDARD CONDUCTIVITIES

"C" VALUES BASED ON RESULTS FROM HOT PLATE TEST METHODS.

Drawn by — LHS
Checked by — VLL
Approved by — VLL

Drawing 103-a
File — Data

Material.	Density in pounds per cu.ft.	Mean test temp. °F.	C = B.T.U. loss per cu.ft. per in. thick per hour per °F. diff.	Authority	t = Commercial thickness	Resistence " $\frac{t}{C}$	S' Inside Surface Factor	$\frac{1}{S'}$	S" Outside Surface Factor	$\frac{1}{S''}$	Remarks.
Wood- Sheathing	34.3	86.°	.95	Bur. Standards	$\frac{13''}{16}$ = .8125	.855	1.5	.667	4.5	.222	Fir, across grain
" -Drop Siding	"	"	"	"	$\frac{1''}{2}$ = .50	.526	"	"	"	"	
" -Lap Siding	"	"	"	"	$\frac{3''}{8}$ = .375	.394	"	"	"	"	
" -Shingles	"	"	"	"	$\frac{1''}{2}$ = .50	.526	"	"	"	"	
Building paper	55.	86 °	.70	Bur. Standards	$\frac{1''}{16}$ = .063	.090	1.75	.571	5.25	.191	1 thickness.
Roofing- Compo.			1.325	Willard & Lichty	$\frac{1''}{4}$ = .250	.188	1.50	.667	4.5	.222	c = 5.3 - actual thick. built-up-tar & gravel.
" -tile			4.0	A.S.R.E.	$\frac{3}{4}$ = .75	.1875	1.25	.80	3.75	.267	
" slate			10.37	"	1" = 1.0	.097	2.0	.50	6.0	.167	
Steel deck			(.96)	Holorib & Truscon		1.04	2.0	.50	4.5	.222	.96 = air to air value of steel deck + roofing
Steel			320.	A.S.R.E	1"	.0031	2.0	.50	6.0	.167	
Glass.			2.06	Willard & Lichty	$\frac{1''}{8}$ = .125	.061	2.0	.50	6.0	.167	
Plaster	46.2	86 °	2.32	Bur. Standards.	$\frac{3''}{8}$ = .375	.161	1.75	.571			
Wood lath & plaster			2.27		$\frac{3}{4}$ = .750	.330	"	"	1.5*	.667	*back side of wood lath & plaster
metal lath & plaster			2.32		"	.323	"	"	1.25*	.80	*back side of metal lath & plaster
stucco	123.2		4.14	A.S.R.E.	"	.181	1.25	.80	3.75	.267	
concrete	140.		8.30	Willard & Lichty	per inch	.120	"	"	"	"	1-2-4 mix.
brick	132.		4.0	"	4"	1.0	1.50	.667	4.50	.222	4.0 = arbitrary mean value for "C".
Hollow Tile.			2.5	A.S.R.E.	per inch	.40	1.25	.80	3.75	.267	2.5 = "
Cinder Concrete Blocks			1.77	Crozier-Straub	per inch	.565	"	"	"	"	
Stone (limestone as masonry)		68 °	6.0	A.S.R.E.	per inch	.167	1.25	.80	3.75	.267	6.0 = arbitrary mean valve for "C".
Sheetrock - Pyrofill			(.25)	-U.S.G. Co.- Gebhardt.	3"		1.75	.571	4.5	.222	.25 = air to air value of 3" monolithic gypsum + roofing
Pyrobar - 3" solid			(.25)	-U.S.G. Co.- Gebhardt			1.75	.571	4.5	.222	.25 = air to air value of gypsum tile + roofing
" 4" hollow			(.20)	"			"	"	"	"	.20 = "
" 5" C.S.			(.30)	"			"	"	"	"	.30 = "
Plaster board	61.0	86 °	1.21	Bur. Standards	3/16" = .3125 3/8" = .375 1/2" = .500	.258 .310 .413	1.75	.571	5.25	.291	Rock lath etc. Sheetrock " Gyplap "
Upson Board	28.5#		.50	A.S.R.E.	$\frac{3''}{16}$ = .1875	.374	"	"	"	"	no temp. given
Cornell Board	28.5#		.50	"	"	"	"	"	"	"	"
Beaver Board	31.0#		.97	"	"	.193	"	"	"	"	"
Thermo Lath.	21.6	86 °	.417	Hunt.	$\frac{1''}{2}$ = .50	1.20	1.50	.667			
Sil-O-Cel	10.6#	86 °	.308	Bur. Standards	1"	3.24	1.25	.80			
"	31.2#	86 °	.622	"	1"	1.61	"	"			

SERVICE DEPT.
The Insulite Co.
Minneapolis - Minn.

STANDARD CONDUCTIVITIES.
"C" VALUES BASED ON RESULTS FROM HOT PLATE TEST METHODS.

Drawn by— LHS
Checked by— VLL
Approved by— VLL

Drawing 103-b
File— Data